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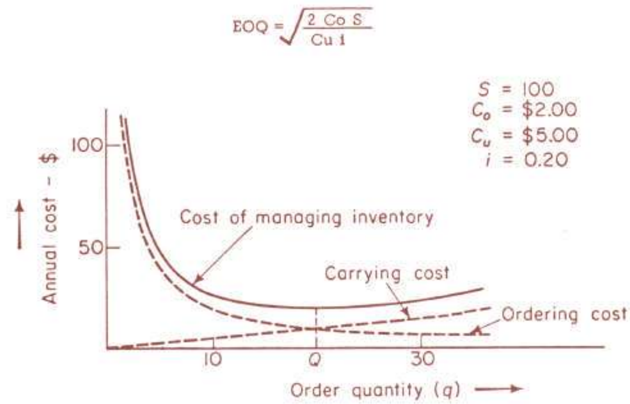

EXHIBIT 1

WHY SCIENTIFIC INVENTORY MANAGEMENT HAS PROVED USEFUL

by Joseph F. Buchan

IN SUCH DIVERSE BUSINESSES as department stores, supermarkets, wholesalers, electro-platers, aircraft manufacturing and paper manufacturing, the systematic application of explicit, scientifically-based, ordering rules has significantly improved inventory management decisions. The development of various inventory management systems using such rules in these industries has been documented.[1] The typical result of installing such a system in a company which did not already have one has been one or both of the following:

1. A reduction in inventory of from 10% to 30%
2. A decrease in stockouts of from 25% to 70%

Frequently these changes have been accompanied by increased sales, and often they have required no increase in the continuing amount of effort devoted to inventory management once the system had been installed. Although the most sophisticated systems make use of a computer, some quite successful systems have been manual, while others have used tabulating equipment.

The reason for the results obtained from the installation of scientifically-based inventory systems lies partially in the large number of reordering decisions which have to be made when managing inventories ranging from several hundreds to many thousands of items, with differing and changing demands. It is unrealistic to expect that all of these decisions will be made in a consistent manner without explicit rules for "when" and "how much" to reorder and a formal system to ensure that the rules are followed. And the rules are not likely to be set properly without an understanding of the relationships between order quantities and inventory costs on the one hand and between inventory levels and stockouts (or customer service levels) on the other. It is in the setting of the rules that an element of the "scientific method" is brought to bear on the inventory management problem.

The concept of "making a model of a system (or operation)", is a fundamental technique in science which turns out to be quite useful in inventory management. A model is a simplified reproduction of the important relationships in an operation or a system. It may be a set of equations, a simple flow chart, or an elaborate computer program. If the model adequately represents the operation, we can

[1] Joseph Buchan and Ernest Koenigsberg, *Scientific Inventory Management,* Prentice-Hall, Inc., 1963

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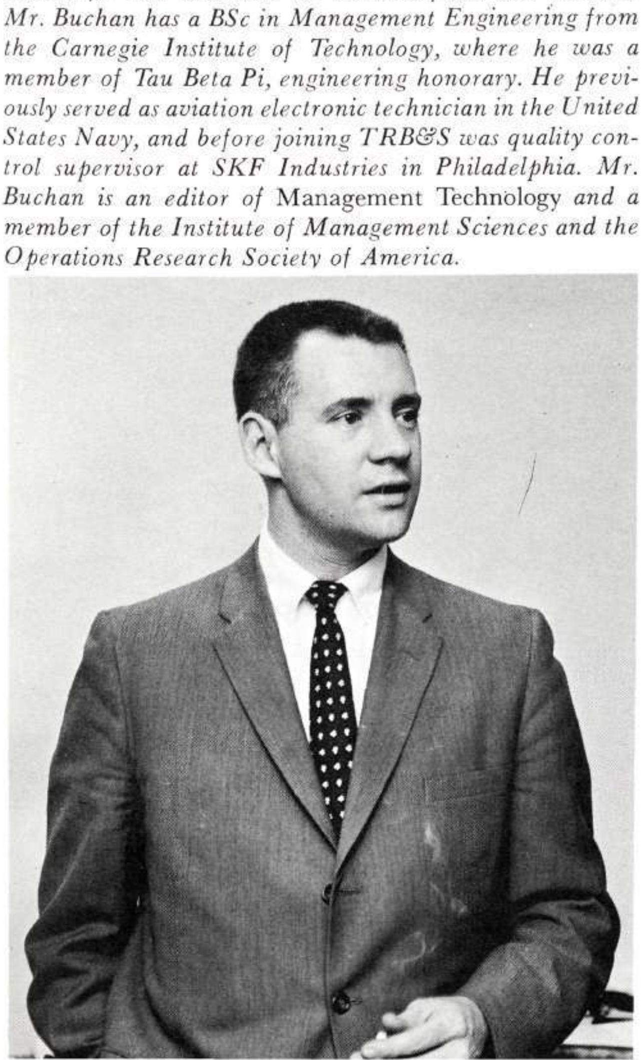

often learn how to improve the operation by experimenting with the model.

The basic inventory model illustrated in Exhibits 1 and 2 is somewhat of a classic, having first appeared in the literature more than thirty years ago.[2] It illustrates the typical assumptions and simplifications of a model, but one which has proven widely useful despite its simplicity. The model shown, which is variously referred to as an Economic Order Quantity system, a reorder point system, or a trigger system, is made up of two parts . . . a model of cost behavior for determining how much to reorder and a model of inventory behavior for determining when to reorder.

The Economic Order Quantity (how much)

Exhibit 1 illustrates the cost model which is used to determine the most economic, or minimum cost, order quantity. The model assumes that the total cost of managing inventory consists of two kinds of costs:

(1) Ordering cost (Co) is the additional cost of placing an order — a cost which is considered to be independent of the size of the order. This might include set up costs in manufacturing, but only purchase order processing costs in retailing. As shown in Exhibit 1, the *annual* cost of ordering decreases at a decreasing rate as the order quantity increases. In other words a specific cost per order is spread over more units per order.

(2) Carrying cost (Cu x i) is the cost of storing inventory plus the opportunity cost of the money tied up in inventory. This is usually expressed as the unit cost of an item multiplied by an annual percentage, such as 20% per year. The *annual* cost of carrying inventory increases

[2] R. H. Wilson and W. A. Mueller, "A New Method of Stock Control", Harvard Business Review Vol. 5, 1926-27

in direct proportion to one-half of the quantity ordered (q/2), because the average level of the inventory will be about halfway between the level just before a reorder is received and the level just after a reorder is received.

As is shown in Exhibit 1, the total annual cost of managing inventory first decreases as the order quantity increases because of the rapid reduction in the unit ordering cost. At some point, this total annual cost begins to increase again as the reduction in ordering cost gets progressively smaller and is eventually outweighed by the increase in carrying cost. The mathematics of this particular model are such that the minimum total annual cost occurs where annual carrying cost equals annual ordering cost, and the order quantity which results in minimum cost can be determined from the formula in Exhibit 1, where S is the annual unit sales.

Based on this cost model, the formula shown will permit determination of the most economic order quantity. Note that the total annual cost curve is rather flat near the minimum point. Thus, the recorder quantity can be varied over some range near the minimum without significantly changing total costs. And because of the square root relationship, a 21% error in determining the carrying cost or the ordering cost will only introduce a 10% error in the determination of the economic order quantity.

The Reorder Point (when to reorder)

Having determined "how much" to reorder, it is also necessary to determine "when" to reorder. The model on which this is based is shown in Exhibit 2. With ideal behavior, a new order quantity would be received just as inventory reached zero. This quantity would be used up at a constant sales rate until another order was received just as the inventory reached zero again.

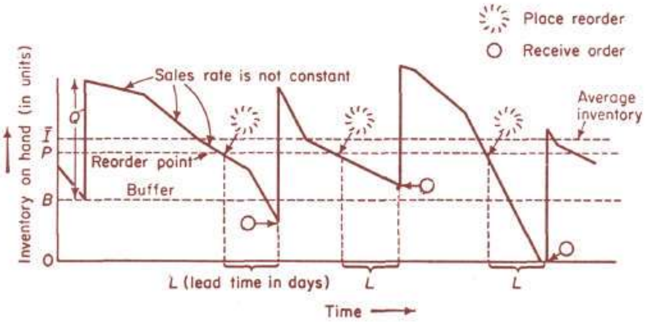

EXHIBIT 2

INVENTORY BEHAVIOR UNDER A REORDER POINT SYSTEM

Since this kind of idealized behavior does not happen in the business world, the model of inventory behavior is made a bit more sophisticated. First, the time lag between placing a reorder and receiving it is recognized. To compensate for this, the average expected sales during this lead time are calculated and that amount is added to zero in computing the reorder point — the level of inventory at which a reorder should be placed.

This is still inadequate because actual sales would exceed average sales in about half of the time periods. Every time this happened there would be a temporary out-of-stock condition (or back order) and probably lost sales. Therefore, a buffer (B) or safety stock is added to expected sales during lead time. The result is the reorder point (P) which is used in this model.

A basic understanding of how buffer stock is determined can be acquired by referring to Exhibit 3, which shows one distribution of individual weekly sales about average weekly sales for 100 weeks. This happens to be a retail item with fairly small weekly sales which fit a particular statistical distribution known as the "Poisson". The pattern of demand on manufacturing or wholesale inventories is likely to fit other distributions such as the "normal" or the "exponential", but the way in which the distribution is used is much the same. It is used to determine the buffer stock required to meet a specific, desired level of protection against stockouts.

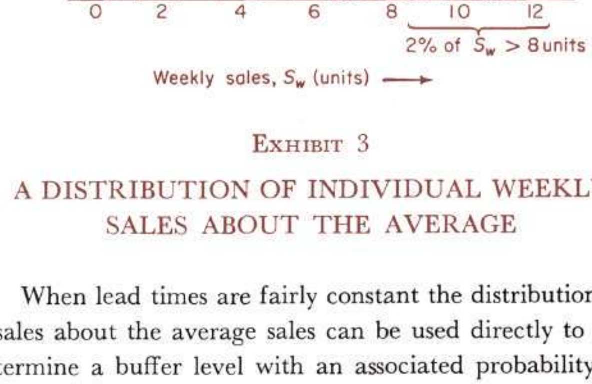

EXHIBIT 3

A DISTRIBUTION OF INDIVIDUAL WEEKLY SALES ABOUT THE AVERAGE

When lead times are fairly constant the distribution of sales about the average sales can be used directly to determine a buffer level with an associated probability of stockout or back orders. If, for example, the lead time in Exhibit 3 were a constant one week with the average weekly sales of four units, and actual weekly sales only exceed eight units in two weeks out of 100, setting the buffer stock at four (reorder point of eight minus average weekly sales of four) should insure that stockouts would not occur more than 2% of the time. If lead times also have a significant variation about the average, the determination of buffer levels and stockout probabilities can be made by a Monte Carlo simulation. In this, tables are set up for the relative occurrence of various lead times and various sales rates. By randomly and repeatedly selecting a combination of a lead time and a sales value from these tables, and plotting the effect on inventory level if the reorder point and quantity rules are followed, the frequency with which inventory would drop to any given level below the reorder point can be approximated. Consequently, the percentage of stockouts which would occur for any given level of buffer stock can be approximated.

Balancing Inventory and Stockouts

Regardless of the method used to determine buffer stocks, the significant fact is that the relationship between inventory levels and stockouts is not linear. As can be seen from Exhibit 3, the proportionate reduction in stockouts gets smaller as we increase inventory from six units to seven and then to eight. A kind of "law of diminishing returns" sets in.

This is shown more clearly in Exhibit 4 for one pattern of sales distribution. Reducing stockouts from 2% to 1% required only a $200 increase in average inventory, while reducing stockouts from 1% to ½% requires an additional $500 increase in inventory.

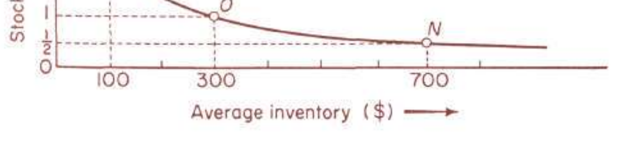

EXHIBIT 4
BALANCING INVENTORY AND STOCKOUTS

In any large inventory, several items may have similar sales — both as to average and as to distribution. The points M and N in Exhibit 4 show the existing stockout and average inventory levels for two such similar items at one company. Obviously these two items were not being controlled to the same extent. Yet there was no good reason for the difference except the large number of items which had to be controlled and the lack of a formal system for controlling them.

By letting management select 1% stockouts as a satisfactory level and by applying the reorder point and reorder quantity rules, the balance of inventory to service levels was shifted to point O for both items. As is shown in the exhibit, the overall stockouts for M plus N and the overall average inventories for M plus N were both reduced.

Undesirable disparities in treatment of different inventory items, similar to that shown in Exhibit 4, are quite common in businesses which process a large volume of inventory transactions, but lack a formal inventory management system. That is why the installation of such a system is often accompanied by simultaneous reductions in stockouts and inventories, however paradoxical this may seem at first glance.

The Proper Inventory to Sales Balance

Lack of understanding of the relations among the inventory variables is also the reason for many companies following an inventory policy which is not the best one, namely that a fixed time supply of each item will be kept on hand. For example, all inventory items may be maintained at a level equal to two months' sales.

The reasons why this is a poor policy can be grasped by a look at the two components of inventory, buffer stock and reorder quantity. Consider the buffer stock. A fixed time supply of items with widely differing sales will not give equal protection against stockouts. For items with a Poisson sales distribution, for example, the buffer stock required to give a particular protection against stockouts varies with the square root of sales. Hence, use of a constant proportion of sales over-protects the high volume items and under-protects the low volume ones. The previous discussion of reorder quantities in connection with Exhibit 1 indicated that the most Economic Order Quantities varies, not in direct proportion to sales, but in proportion to the square root of sales.

Exhibit 5 shows how the time supply of inventory should vary with sales. Note that the scales are logarithmic so that the straight, slanted line relating the proper inventory level to the sales volume actually represents a non-linear relationship. But it is definitely a relationship in which the time supply decreases as sales increase. For item M with $200 annual sales, inventory should be at 20% of annual sales, while inventory of item Z should be at 2.5% of annual sales of $10,000.

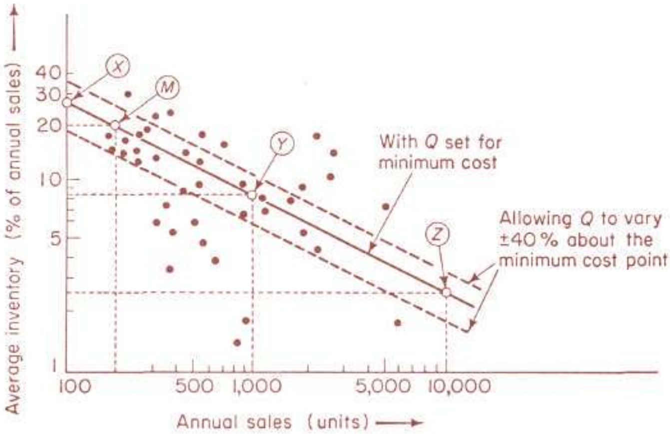

EXHIBIT 5
THE PROPER BALANCE OF INVENTORY TIME SUPPLY TO SALES

The scattered dots on the exhibit represent the actual relation between sales and inventory time supply for a number of different items under existing inventory procedures at a company which did not attempt to maintain a constant time supply. After the application of Scientific Inventory Management rules, all of these relationships were shifted to fall within the slanted, dotted lines, which represent the EOQ plus and minus 40%. (As mentioned in connection with Exhibit 1, the total inventory cost changes relatively little for a range of values about the EOQ, and carrying and ordering costs are seldom known precisely enough to warrant insistence on the exact EOQ.) The net result was a reduction in both inventory and stockouts.

Selectivity

Almost every inventory, regardless of type, displays one characteristic which should be mentioned because it often enables inventory management to be significantly improved without increasing the total amount of effort spent, by selective re-allocation of effort. This characteristic is illustrated in Exhibit 6, which shows the results of classifying all items in an inventory into three groups based on their relative activity. Group A, which includes only 7% of the items, accounts for 51% of the sales and 49% of the inventory dollars.

Class	No. of Items	% of All Items	% of Sales	% of Average Inventory
A	156	7%	51%	49%
B	835	35	38	37
C	1409	58	11	14
	2400	100%	100%	100%

EXHIBIT 6
A TYPICAL CLASSIFICATION OF INVENTORY ITEMS

Re-allocating a limited amount of inventory management effort so that more of it is concentrated on the class A items will often improve the overall inventory picture. In a system relying on periodic inventory counts, for example, the A items might be counted every two weeks while the C items are counted only every six weeks. In addition, the customer service (or instock) levels might be set at 98% on the A items and 85% on class C items. The existence of a pattern much like that shown in Exhibit 6 is so common that an opportunity for selective allocation of effort nearly always exists.

Variations From The Basic Model

There are many useful variations on the basic inventory model which was just discussed. The above model assumes that perpetual inventory records are continually reviewed so that knowledge of reaching the reorder point is instantaneous. Where inventories are periodically reviewed, a provision can be made for sales during the review period (time between physical counts).

In another situation, where periodic inventory reviews are made and ordering costs are unimportant, a replenishment level system may be appropriate. Such a system might be used, for example, where reorders merely transfer company owned inventory from a central warehouse to decentralized selling locations. In the replenishment system, the order quantity is not constant, but is equal to the difference between a fixed replenishment level and the actual inventory level at the time of the review.

Conclusion

These variations need not concern us. The main purpose of this discussion is to indicate, by specific reference to one simple but useful inventory model, how the application of Scientific Inventory Management has been of use in improving inventory management. Its utility stems from the fact that it provides specific inventory reorder rules, based on an explicit analysis of their effect on inventory costs and customer service levels, which can ensure consistent inventory management practices in conformance with inventory management policies.